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NRL REPORT 3556

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SOUND TRANSMISSION MEASUREMENTS AT 8 AND 16 KC IN CARIBBEAN WATERS, SPRING, 1949

NAVAL RESEARCH LABORATORY

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NRL REPORT 3556

SOUND TRANSMISSION MEASUREMENTS AT 8 AND 16 KC IN CARIBBEAN WATERS, SPRING, 1949 (C)

R. J. Urick

November 11, 1949

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Dr. H. L. Saxton, Superintendent, Sound Division

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ABSTRACT

Measurements of sound transmission at 8 and 16 kc have been obtained through the use of a submarine-mounted sound projector and a string of six hydrophones suspended at different depths from a surface ship. The use of a submarine-mounted projector thus provided a sound source of controllable depth, range, and frequency. Data were obtained in Caribbean waters on a cruise between Key West, Florida and San Juan, Peurto Rico during February and March, 1949. Essentially simultaneous measurements were made at 8 and 16 kc. The resulting mass of data was found to be most lucidly presented when plotted as transmission-anomaly cross-sections. These were found to have features only partially explainable from the ordinary bathythermograph trace.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem S02-03R
NR 522-030

with weights, and so attached to the remainder of the cable string that they hung free of it when the string had any inclination to the vertical. A picture of this arrangement, taken in the laboratory, is shown as Figure 1.

Any one of the hydrophones could, by means of a switch, be connected through an attenuator to the input of a tuned amplifier. The amount of attenuation needed to give a constant reading on an output meter provided a measure of sound level independent of the gain characteristic of the amplifier. As only relative levels were desired, no calibration of the hydrophone-attenuator-amplifier system was required.

The sound source consisted of a cylindrical underwater telephony transducer 10 inches long and 9 inches in diameter mounted vertically on a submarine. One of the two submarines (the DIABLO, SS 479) had this type of transducer already installed on its cigarette deck forward of the conning tower; the other submarine (the SEA POACHER, SS 406) required a special installation of this transducer.

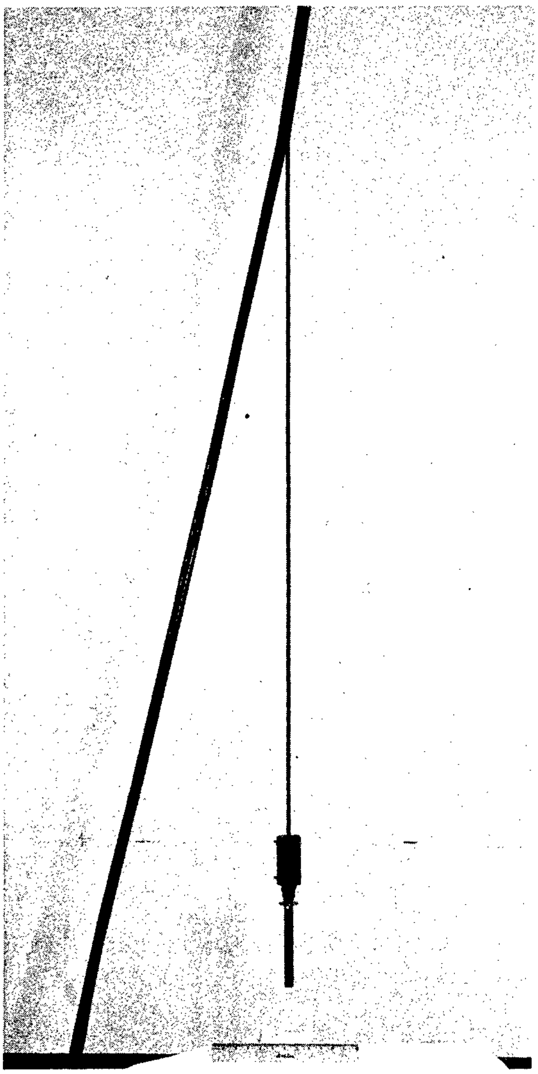


Figure 1 - B19-H hydrophone and its suspension from cable string

The submarine made runs at constant depth from a minimum range of about 750 yards out to the maximum range at which a measurable sound level could be obtained. In order to avoid shielding of the sound emitted from the transducer by the conning tower and wake of the submarine, a curved track was taken so as to keep the E-PCS-1426 at least 25° off the bow or stern. A diagram of the plan of the runs constitutes Figure 2.

Thus in essence the submarine provided a sound source of constant depth and continuously variable range. To determine the

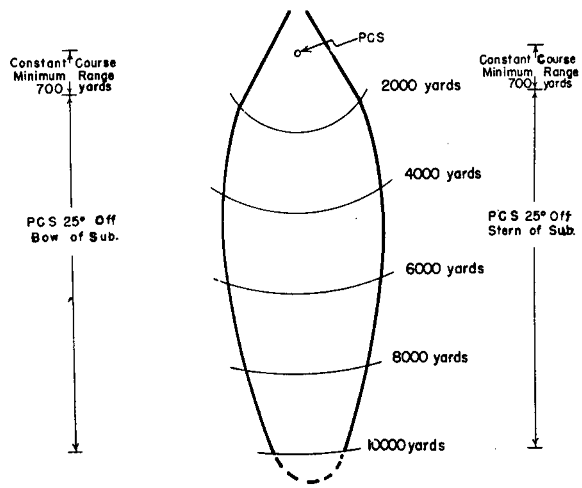


Figure 2 - Track of submarine

range from the E-PCS-1426 to the submarine, alternate periods of signal transmission from the submarine and echo ranging from the PCS were employed. For the purpose of obtaining enhanced echoes at long ranges, an automatic keying device was installed between the receiver and the driver of the submarine's sonar, thus converting it into an echo repeater. During the transmissions of one minute duration, the level at each of the six hydrophones was determined. Alternate transmission periods were made on 8 kc and 16 kc, thus providing nearly simultaneous data at these two frequencies for the same depth and range combination.

During the period 11 February to 4 March 1949, the E-PCS-1426 cruised in company with the DIABLO, SS 479, from Key West to Guantanamo, Cuba, and with the SEA POACHER, SS 406, from Guantanamo to San Juan, P. R. Runs were made at 10 locations along this route, as shown on the chart of Figure 3. Sea states varied from zero to four on the operating days; higher seas were experienced south of Cuba, where they were too great for the E-PCS-1426 to lie to. Bathythermograms were obtained several times during each day's operations.

DATA ANALYSIS

The field data consisted of a multiplicity of relative level measurements for various ranges at different source depths and at the two frequencies, 8 and 16 kc. It is convenient to remove from such field transmission data the loss due to spherical spreading relative to some reference distance from the source, and so remain with the "transmission anomaly" (transmission loss in excess of the loss due to spherical divergence) at the various ranges. Figure 4 illustrates this process for a representative run at 16 kc with a source depth of 28 feet. The measured levels in db for the six hydrophones were plotted relative to an arbitrary origin. For subsequent contouring it was found necessary to draw a smooth (dashed) curve through the plotted points. Through this curve at a range of 750 yards, a line (on semi-log paper) with a slope of 6 db per distance double was drawn. The difference between this line and the curve is the transmission anomaly in db referred to 750 yards.

This reduction process obviously possesses a degree of arbitrariness in the drawing by eye of the smooth curve through the measured points. The scatter of the raw data represents actual fluctuation of sound level in the ocean modified by estimation errors of the average values of a fluctuating meter. The average difference between the smooth curve and the measured points for all the data was found to be 1.6 db.

The resulting anomalies were plotted against range in kiloyards and depth in feet, and contoured, in order to provide what might be termed transmission anomaly cross-sections of the ocean for a single source depth. Figures 5 to 14 show such cross-sections for frequencies of 8 and 16 kc. A typical BT obtained on the E-PCS-1426 during the day's operations is shown lowermost in each figure. At the point representing the depth and range of each hydrophone is the value of anomaly obtained from plots similar to Figure 4. These values have been contoured in 5 db steps. Shaded portions show regions in which the sound level was found to be greater than it should be if only spherical spreading were operating. The areas in which the data for each figure was obtained may be found by means of the date and reference to Figure 3.

DISCUSSION

All of the bathythermograms, with the exception of one (that of March 14, 1949) near Key West, show nearly isothermal water down to a depth of 200 to 400 feet. While slight

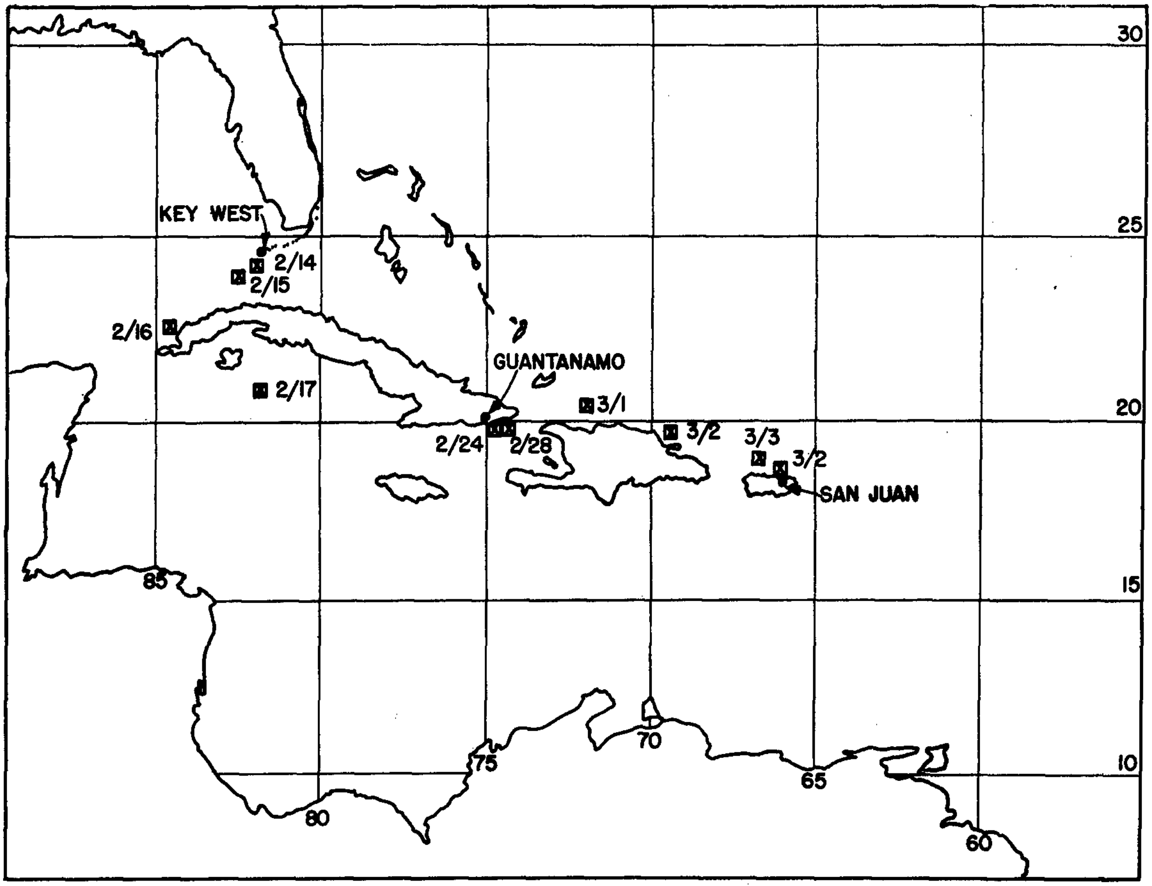


Figure 3 - Chart of operating areas

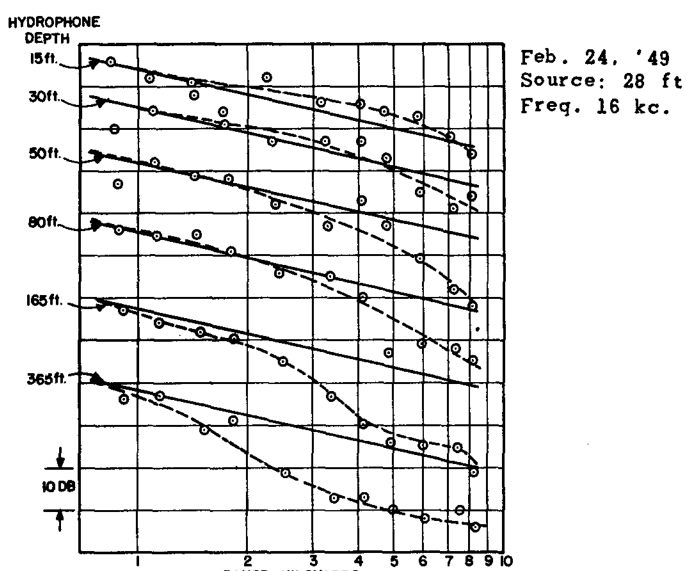


Figure 4 - Example of data reduction process for a typical run

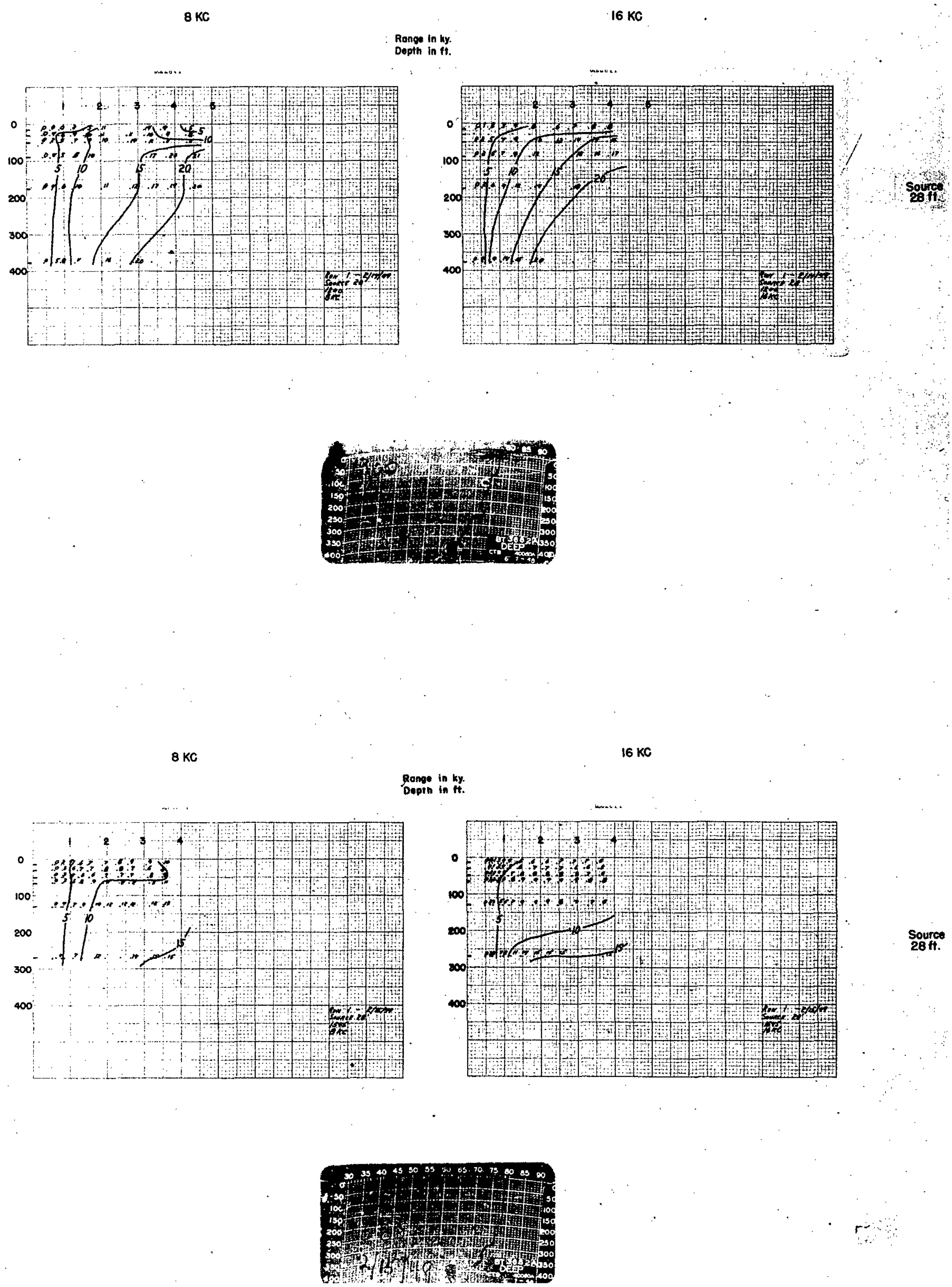


Figure 5 - Transmission anomaly cross-sections, dates 2/14/49 and 2/15/49 (depth in ft vs. range in ky)

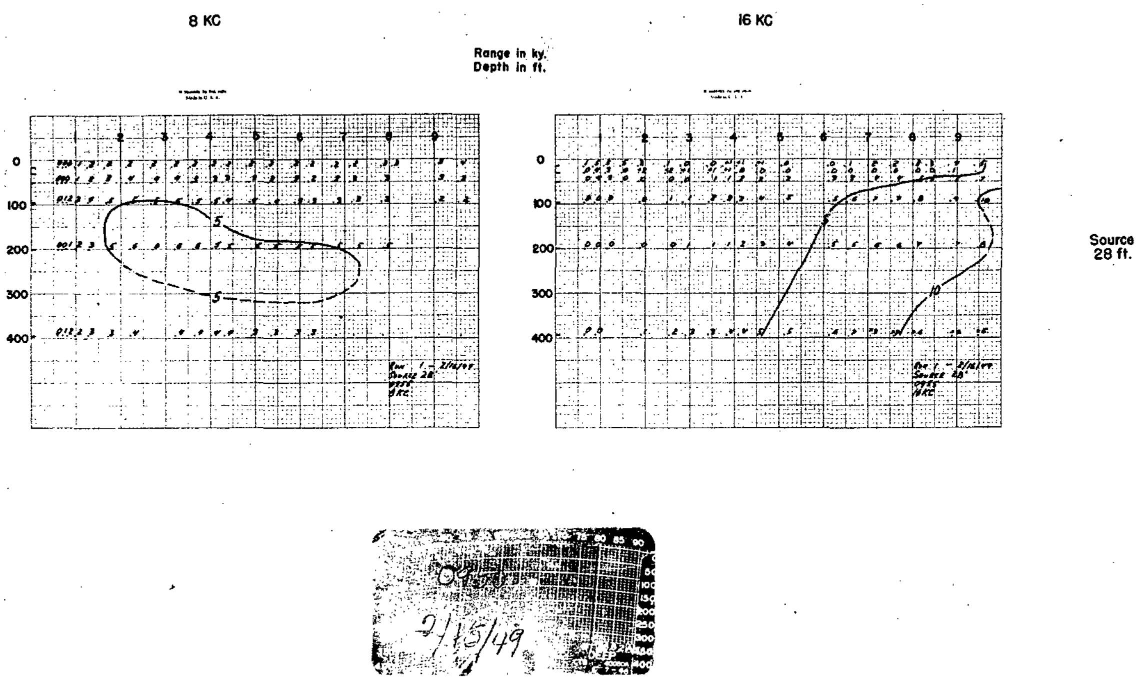


*Figure 6 - Transmission anomaly cross-sections, date 2/16/49
(depth in ft vs. range in ky)*

temperature gradients are present therein from time to time, nevertheless this layer is of sufficiently slight negative gradient that the velocity of sound still increases with depth. This means that in nearly all cases a surface-bounded sound channel 200 to 400 feet thick exists, in which a portion of the emitted sound is trapped between the surface and the lower boundary of the channel. In the channel sound rays are curved upward and sound travels to great ranges by successive reflections from the surface. This trapping results in transmission anomalies smaller than would exist in isovelocity water, and should be accompanied by long echo and listening ranges. In the propagation of microwaves such surface ducts are of common occurrence. To realize the full effects of such a channel, both source and receiver must be located in the channel a considerable distance apart.

In general, these statements are borne out by the data. For example, even at the comparatively short range of 5,000 yards, approximately one-half of the anomalies at 8 kc are equal to or less than would be found in isovelocity water, using the best present value for minimal attenuation coefficient. Some regions are observed, shown shaded in the cross-sections, where the sound level is greater than it would be even in an isovelocity, absorption-less medium. When either or both source and receiver are below the isothermal layer, large anomalies are observed. Near the surface where the water is subject to local heating and cooling, there are regions of extremely high and low anomaly especially when the source is near the surface. Such conditions must result from local and transient heating and cooling of the surface water.

Some systematic dependence of anomaly with hydrophone depth was found. When all source depths are averaged, the average anomaly plotted function of hydrophone depth is given in Figures 15 and 16 for several different ranges for 8 and 16 kc, respectively. The anomaly is seen to be somewhat greater at the deeper hydrophone depths.

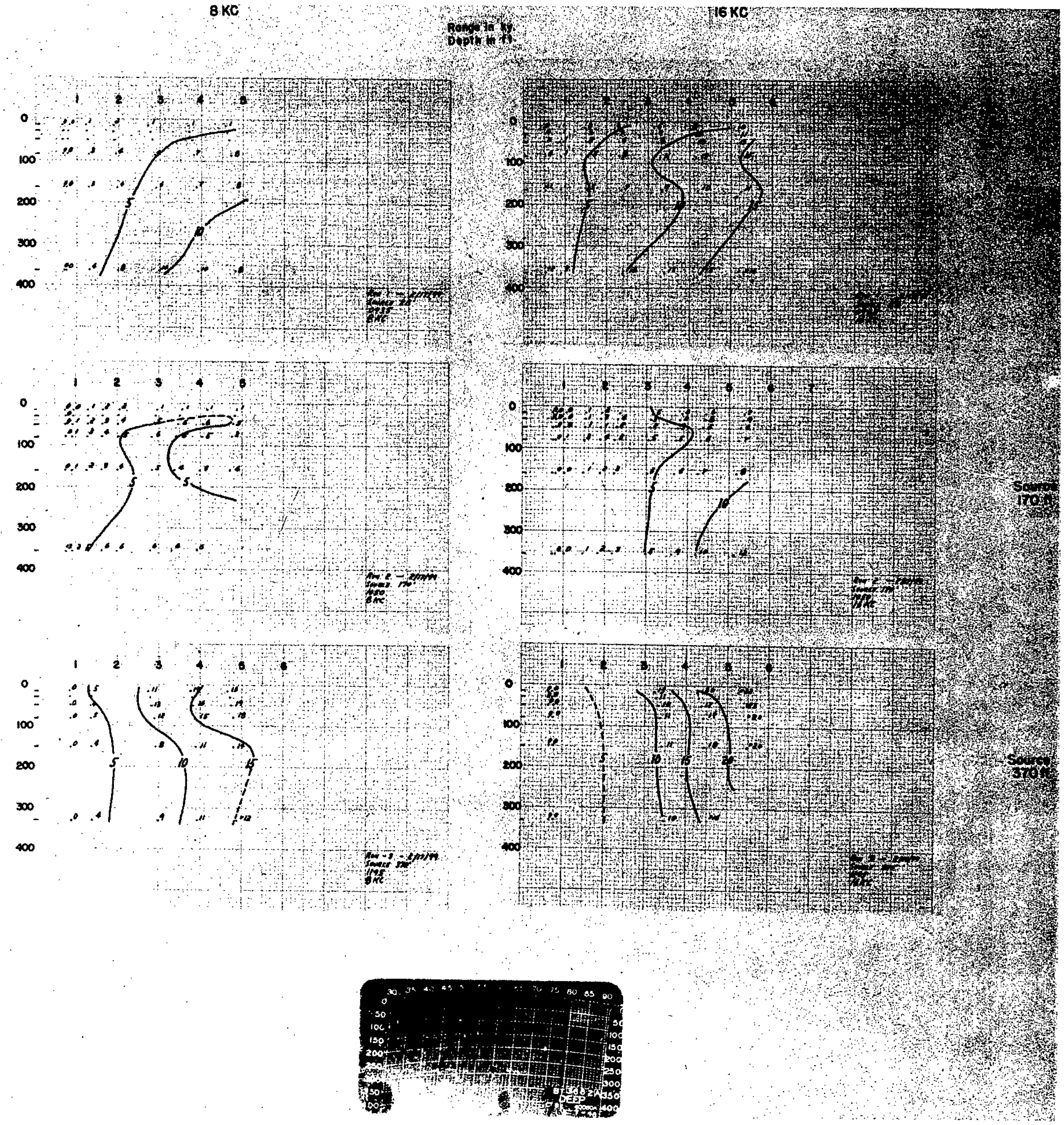


Figure 7 - Transmission anomaly cross-sections, date 2/17/49 (depth in ft vs., range in ky)

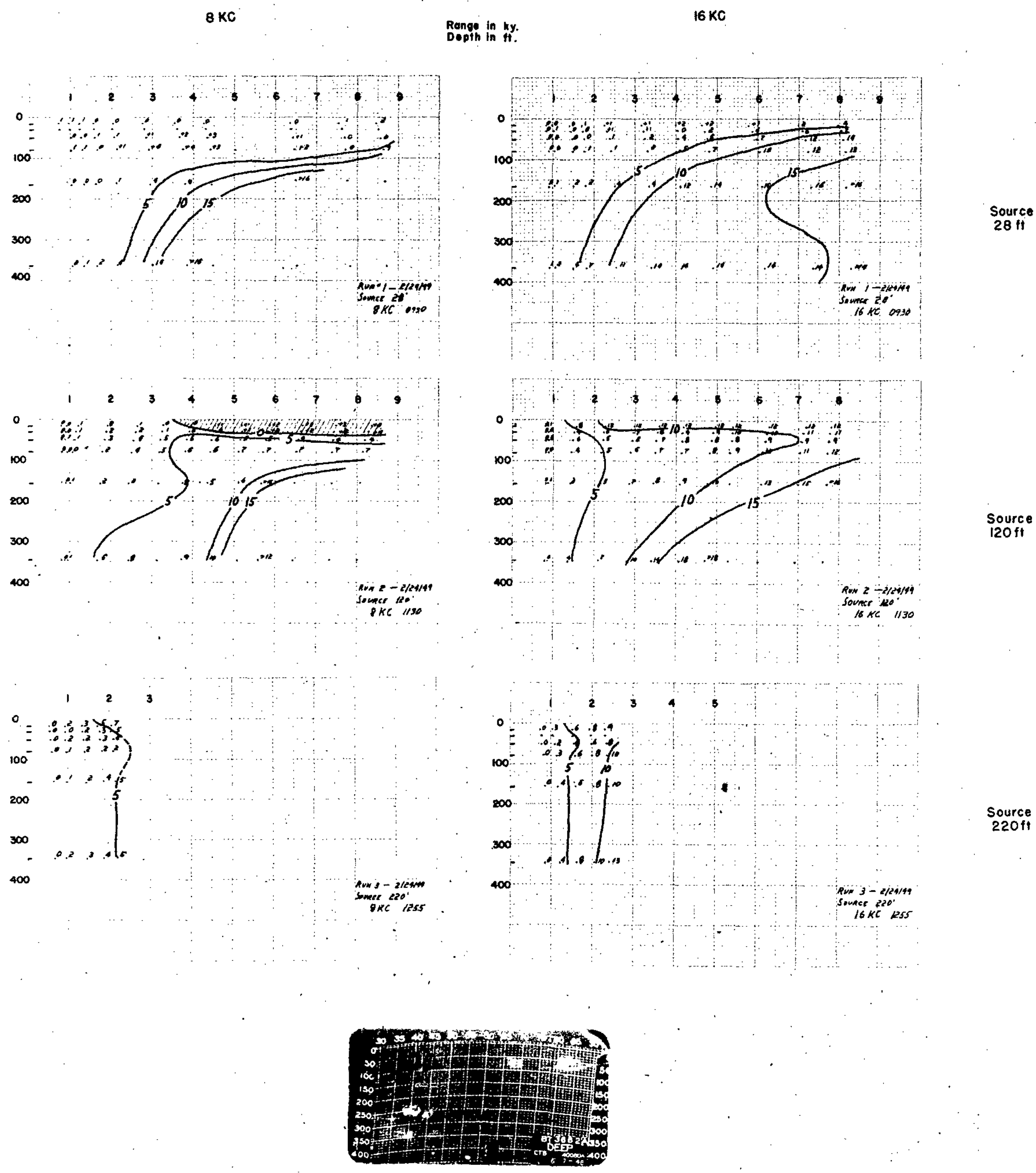


Figure 8 - Transmission anomaly cross-sections, date 2/24/49 (depth in ft vs. range in ky)

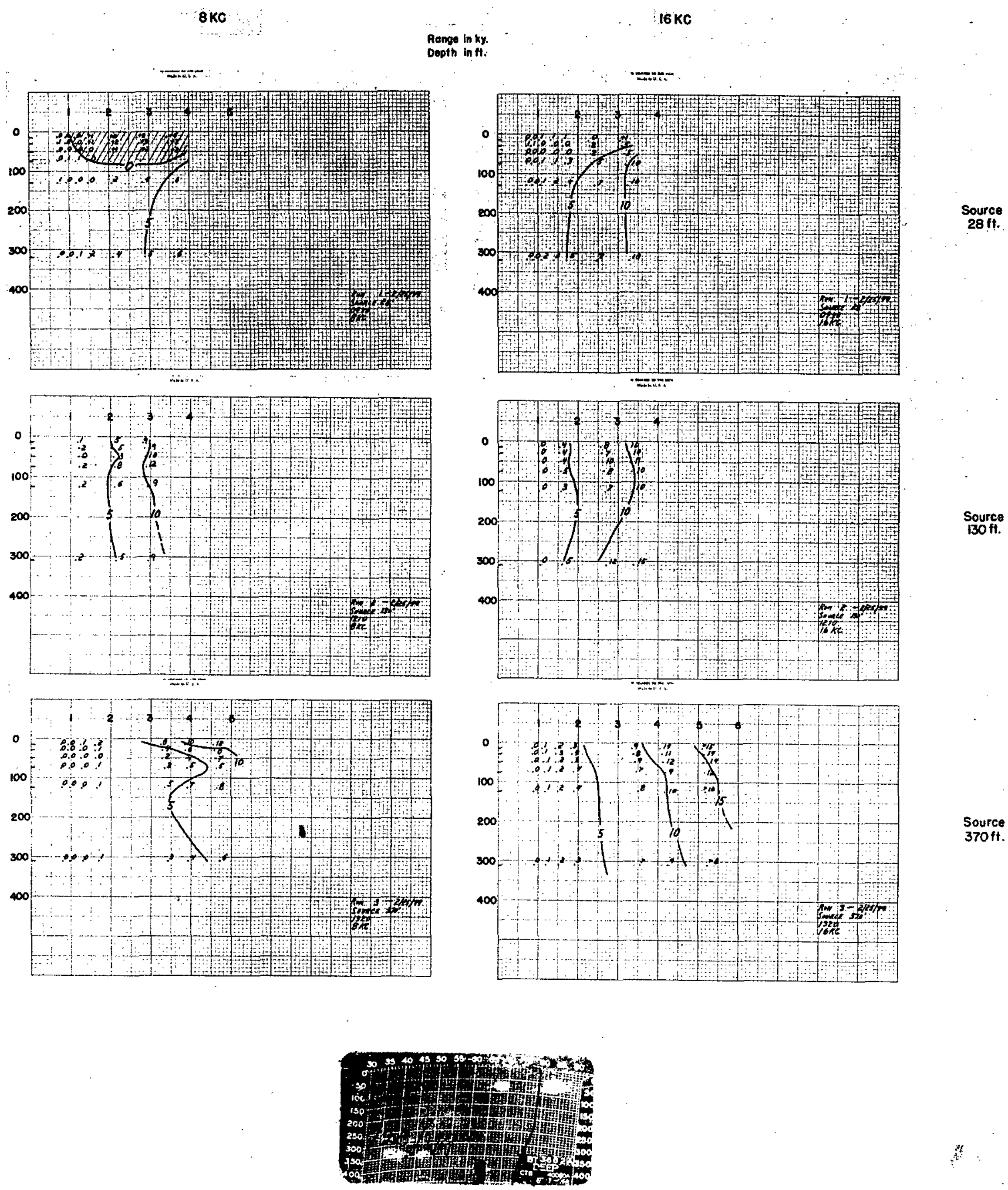


Figure 9 - Transmission anomaly cross-sections, date 2/25/49 (depth in ft vs. range in ky)

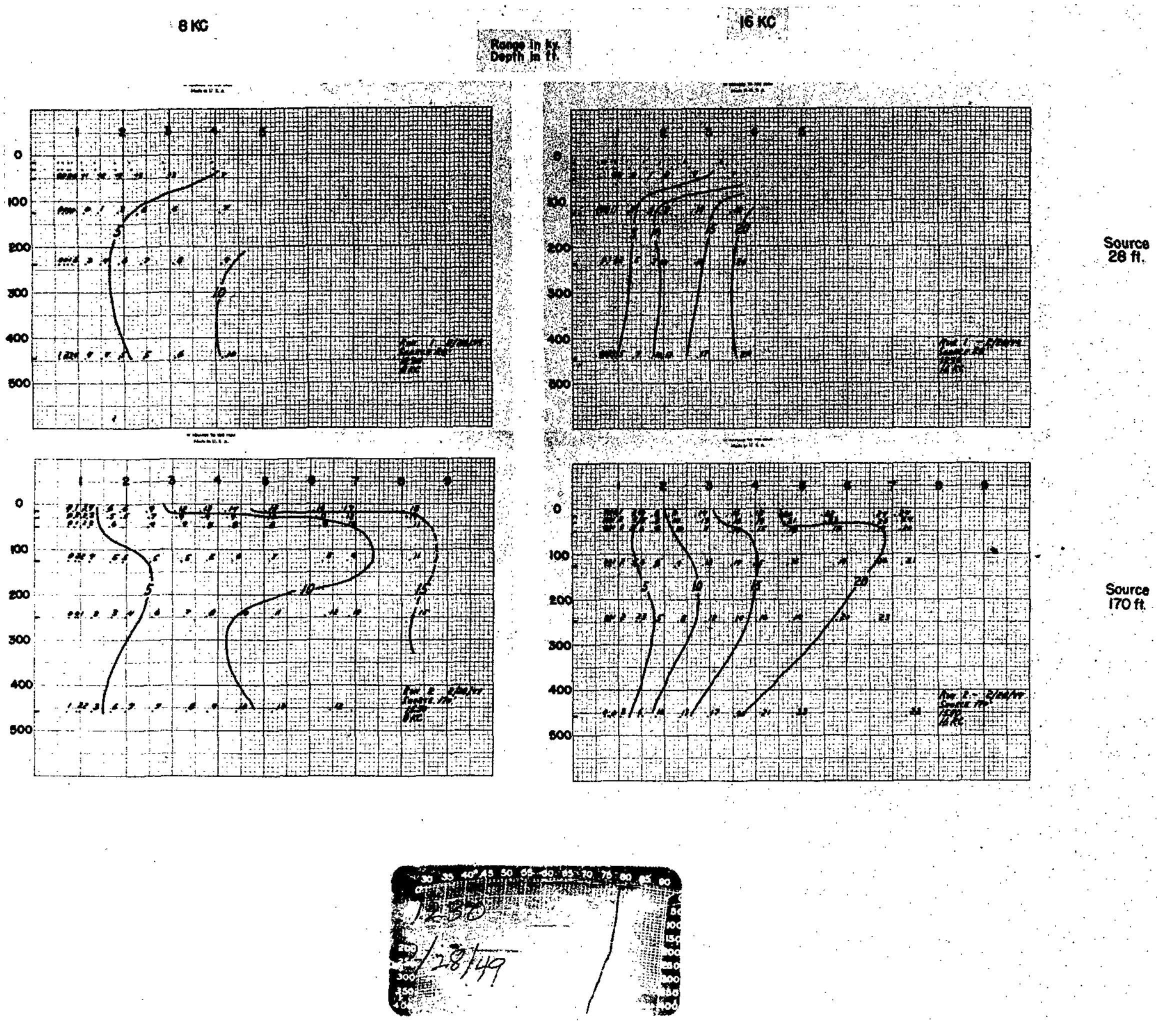
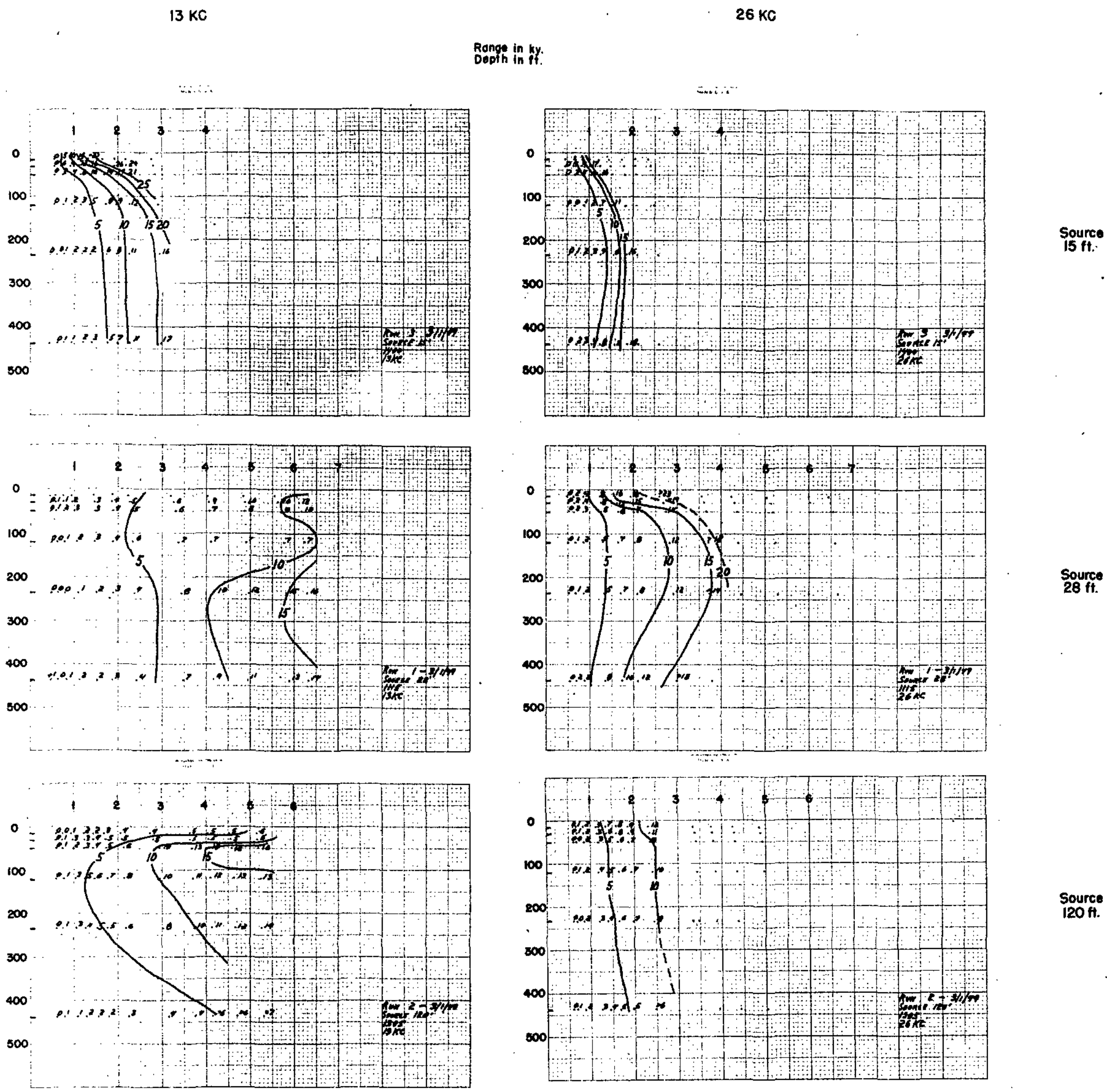


Figure 10 - Transmission anomaly cross-sections, date 2/28/49 (depth in ft vs. range in ky)



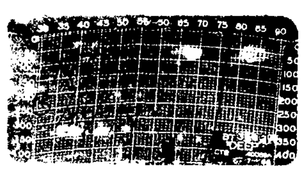


Figure 11 - Transmission anomaly cross-sections, date 3/1/49
(depth in ft vs. range in ky)

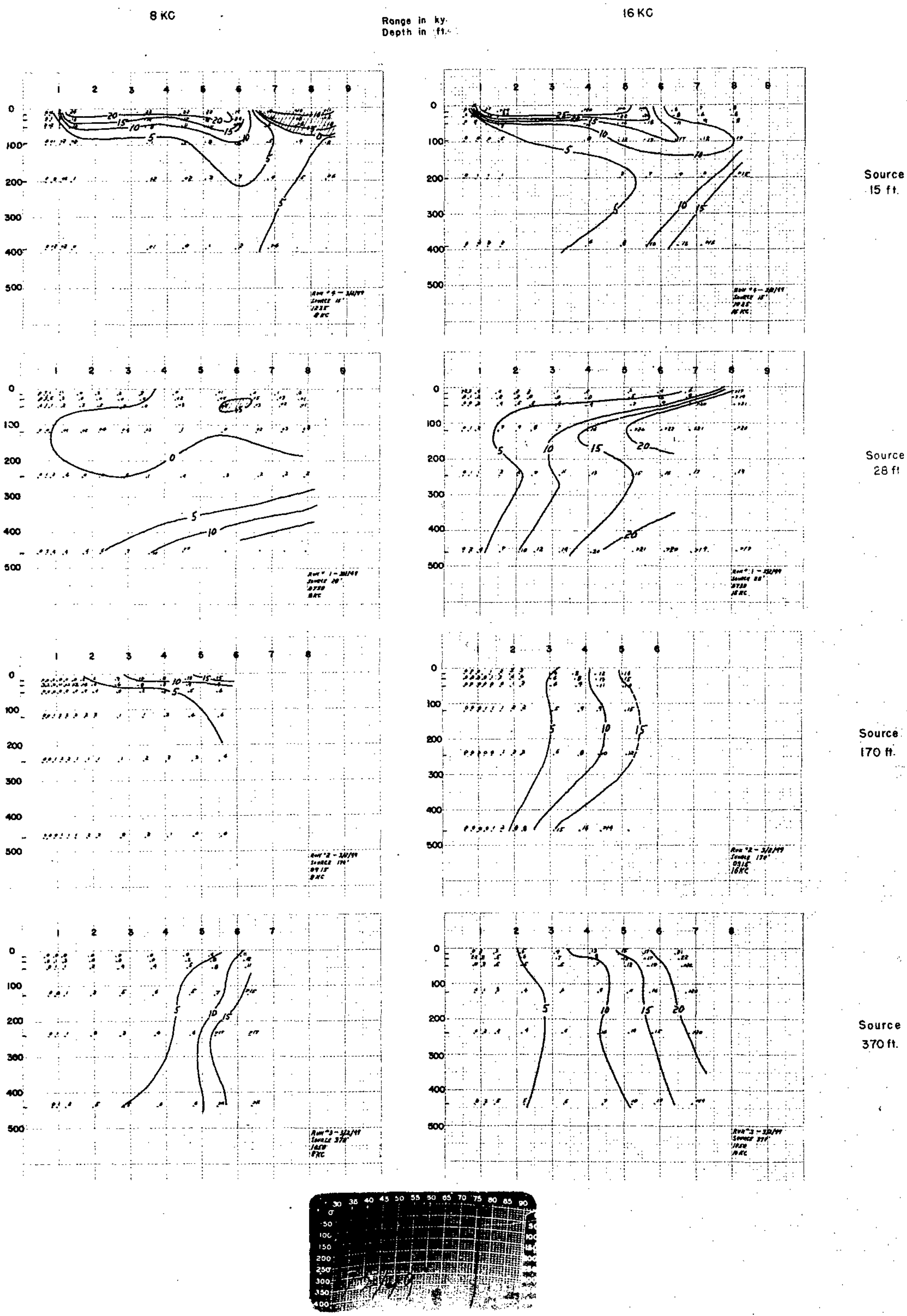


Figure 12 - Transmission anomaly cross-sections, date 3/2/49 (depth in ft vs. range in ky)

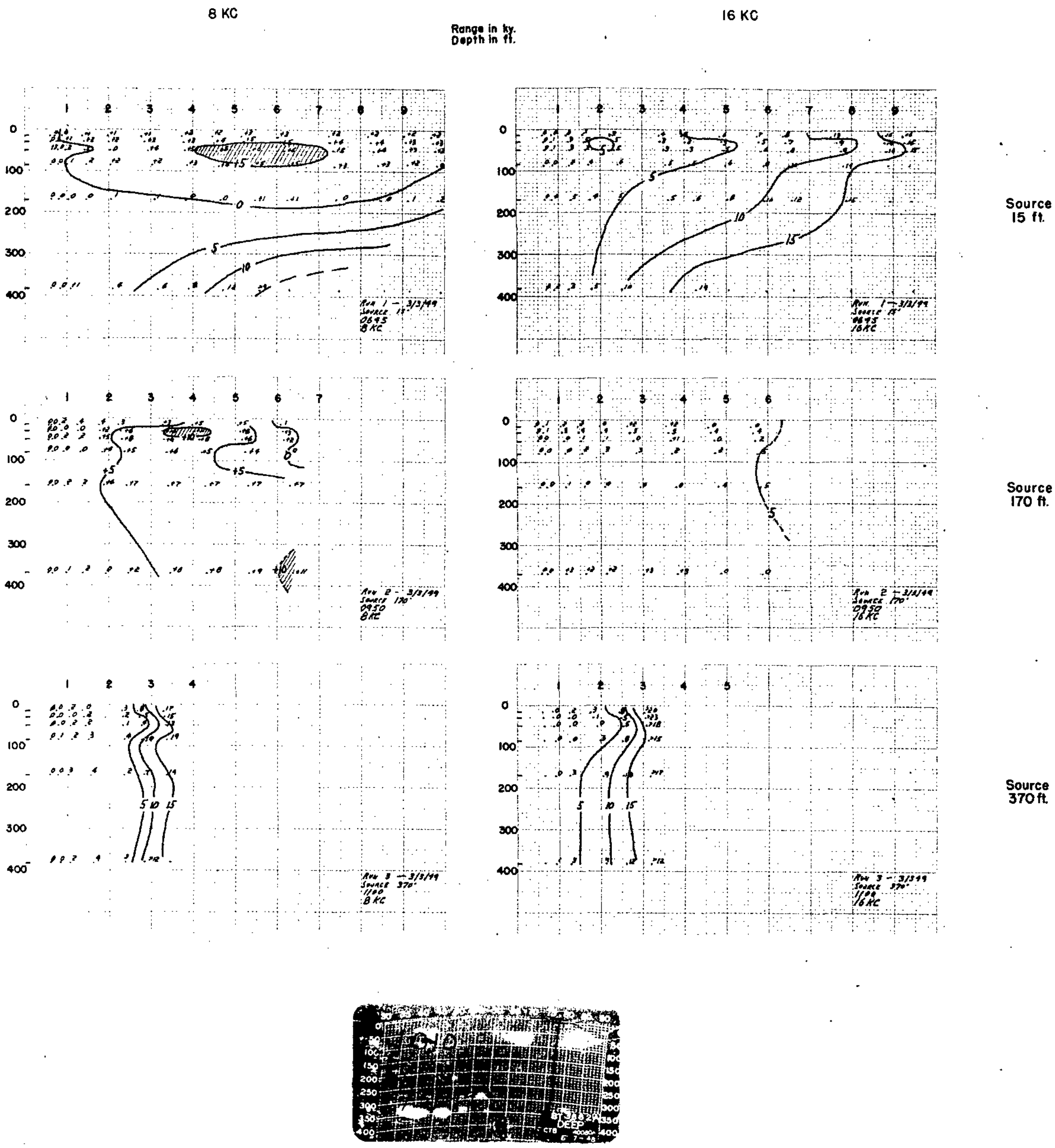


Figure 13 - Transmission anomaly cross-sections, date 3/3/49 (depth in ft vs. range in ky)

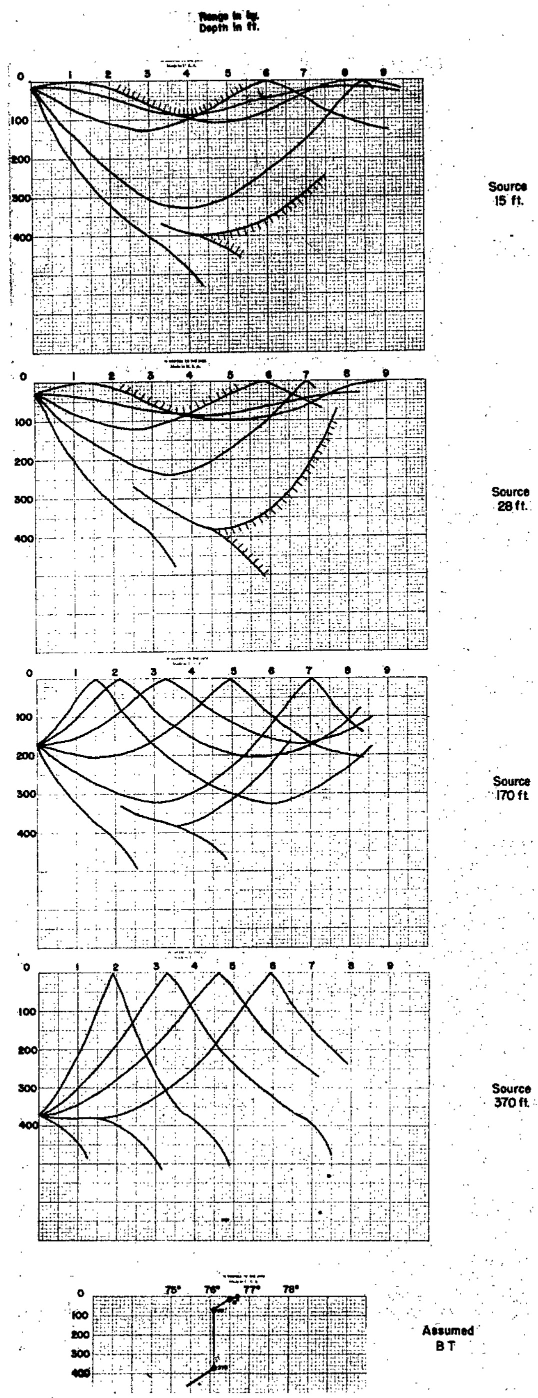


Figure 17 - Ray diagram corresponding to Figure 13 of 3/2/49 (depth in ft vs. range in ky)

The transmission anomaly is ordinarily thought to result from the combined effects of two independent causes. One is the loss due to absorption and scattering, and is for the most part dependent only on frequency. At the present time it is not believed to be dependent upon thermal and salinity gradients, except possibly in a subsidiary manner. The other is the loss due to refraction, resulting in a redistribution in space of the emitted sound. The refraction loss is normally determined by the bathythermograph and is commonly considered to be independent of frequency. Comparing the anomaly for 8 and 16 kc we should then find a difference which depends only on range, and not to a first approximation upon water conditions, and which represents the difference in loss due to absorption alone. Using values of 1.0 db per kiloyard at 8 kc and 2.8 db per kiloyard at 16 kc[10] we should expect an anomaly difference of 1.8 db for each kiloyard in excess of the reference range of 750 yards. Thus at 5,000 yards, the 8 and 16 kc plots should differ by 7.8 db in all cases, and be independent of depth. Those runs which extend to 5,000 yards actually show an average anomaly of 3.3 db at 8 kc and 9.8 db at 16 kc, a difference of 6.5 db.

The discrepancy between this last value and 7.8 db may represent some systematic error in the data, or else an indication that absorption is somewhat less in Caribbean waters than in waters where previous data have been obtained. Also it should be mentioned that the average anomalies at 5,000 yards are smaller than would be given by the best currently available values of attenuation coefficient alone, indicating that a divergence loss less than spherical (upward refraction) prevailed for the runs extending to 5,000 yards or beyond.

Occasionally there are more striking differences in the anomalies at 8 and 16 kc. For example, on March 2, 1949 (Figure 12) with the source at 28 ft. the level dropped off much more quickly at the shallow hydrophones between 6 and 8,000 yards at 16 kc than at 8 kc. Conversely in the same figure, with the source at 170 feet, the level at the shallow depths fell off with range more quickly at the lower frequency than at the high.

A ray diagram has been drawn for this particular day, and is shown in Figure 17, with the actual BT, as closely as it could be read, simulated by the BT shown at the bottom of the figure. A comparison with the actual measurements of Figure 13 shows that the ray diagrams elucidates only the rough features of the sound field. For example, the low intensity zone at 4,000 yards and the high intensity region at 8,000 yards near the surface for a source depth of 15 feet are borne out by the ray diagrams.

Some error in drawing the ray diagram is caused by the difficulty in reading slight gradients from the BT, and the impossibility of determining the temperature distribution accurately with a single BT over a distance of several miles during the period needed for a run. More frequent observations, from both ends of the acoustic path, with a more sensitive temperature or velocity measuring device are needed to specify the velocity distribution more completely. However, the ray diagram, since it ignores phase relationships between rays, treats all frequencies alike and cannot explain the difference between 8 and 16 kc mentioned above. Of greater utility in such cases is the normal mode theory, which so far has not been applied extensively to the propagation of sound in deep water.

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[10] *NDRC Summary Technical Report, Division 6, Vol. 7, Figure 50, p. 57.*

* * *

NAVY-DPPO PRNC. WASH., D.C.

UNITED STATES GOVERNMENT

memorandum

7103/133

DATE: 19 November 1996

FROM: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF. (a) FOR DECLASSIFICATION

TO: Code 1221.1

VIA: Code 7100

REF: (a) NRL Report #3556 by R.J. Urick, 11 Nov 1949 (U)
(b) NRL Classification Change Notice 26-62 of 2 May 1961

1. Reference (a) is a report on a series of sound propagation measurements between 8 and 16 KC in Caribbean waters south of Guantanamo Bay, Cuba. These tests were in support of active sonar reduction in operating frequency following World War II. The major frequency of sonars during World War II was 25 kHz. The research and development at NRL following the war progressed to 10 kHz, 5 kHz, and 2 kHz. This report consists of environmental and transmission loss measurements.

2. The technology and equipment of reference (a) have long been superseded. The current value of this report is historical.

3. Reference (a) was declassified by reference (b).

4. Based on the above, it is recommended that reference (a) be released with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
Acoustics Division

CONCUR:

Edward R. Franchi 11/20/96

EDWARD R. FRANCHI Date
Superintendent
Acoustics Division

Completed 1-11-00 an

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